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TAXING INTERMEDIATE GOODS TO COMPENSATE FOR DISTORTING TAXES ON HOUSEHOLD CONSUMPTION

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Taxing intermediate goods to compensate for distorting taxes on household consumption

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Abstract: In contrast to the classic result in Diamond and Mirrlees (1971) that fiscal taxes should not be levied on intermediate use of goods, Newbury (1985) showed that, in a closed economy with Leontief technology, input taxes should be used to indirectly tax commodities that for some reason are untaxed in final consumption.

This paper extends the Newbury result to more general cases; i.e., to open economies with substitution possibilities in the production functions. Moreover, it shows that the welfare maximizing proportion between the tax rate for intermediate use by firms and final demand by households declines with higher elasticities of substitution in production functions and with higher price elasticities in import demand functions and export supply functions. It also shows that the welfare maximizing proportion of tax rates between households and firms for one commodity will depend upon the corresponding proportion of tax rates for important substitutes for that commodity. These results are shown both in stylized Computable General Equilibrium (CGE) models and in an applied CGE model of the Swedish economy where the tax on electricity is used as an example.

Keywords: Optimal taxation, CGE-analysis

JEL Code: H21, D58

1 Introduction

The efficient distribution of taxes on commodities between final and intermediate use depends upon the purpose of the tax. In the following, taxes with the purpose of changing behaviour will be called pigovian taxes, while taxes with the purpose of raising government revenue will be called fiscal taxes. The conventional wisdom is that a pigovian tax should have the same rate for all users, while a fiscal tax only should be levied on final consumption. There are, however, important exceptions to this simple rule. In the case of pigovian taxes there are arguments for lower taxes in industries competing in the world market (Hoel 2001). In the case of fiscal taxes deviations from the optimal tax rates in final consumption may call for compensating taxes on intermediate use (Newberry 1985).

This paper limits the analysis to fiscal taxes, and analyses the efficient distribution of the tax burden between intermediate use by firms and final consumption by households when not all commodities in the economy are taxed. Diamond and Mirrlees (1971) showed that the efficient tax rates for intermediate consumption are zero if tax rates for final consumption are at their optimal levels. The classical lesson is that one should avoid disturbing the efficiency in production and minimize the disturbance of efficiency in consumption. To this aim the Ramsey rule should be applied, i.e. the tax base should be defined as broadly as possible and be corrected for price elasticities so that goods with low price elasticity have the highest tax rate. However, an exception to this rule arises when some commodities cannot be taxed directly (Newberry 1985). In that case input taxes should be used to tax the otherwise untaxed commodities through the use of inputs in the production process.

The literature on optimal fiscal taxation of intermediate goods is very scarce. Starret (1998) analyzes the cost of taxes on intermediate goods but does not analyze optimal levels of these taxes. The Diamond and Mirrlees result seems to have been considered as an end of discussion of optimal fiscal taxes on intermediate goods. In the real world, however, politicians often fail to set household taxes at their optimal level, either due to difficulties in estimating the optimal rates or because of other objectives for tax policy. The exception discovered by Newbury therefore needs much more interest from economists and politicians. It may, for example, be the case that Newbury's result is not fully recognized in the political discussion on energy taxes. In many OECD countries electricity tax rates are substantially higher for households than for industry.[1] This would be supported by Diamond

[1] Energy Prices and Taxes, http://data.iea.org

and Mirrlees' result only if an electricity tax is an optimal fiscal tax, i.e. if an electricity tax is less distorting for the choices of households than, for example, the VAT.[2]

This paper deepens the Newbury analysis and considers more realistic models with international trade and substitutability in production functions. The Newberry analysis was done in a closed-economy model with Leontief technology, and in retrospect his result is pretty trivial. If the use of inputs is always proportional to output, then a tax on an input would have exactly the same effect on the decisions of firms as a tax on output. If the tax on a specific output deviates from the optimal level, it is always possible to impose an appropriate tax or subsidy on the use of inputs to achieve the optimal prices in final consumption. With Leontief technology, taxes on inputs would not distort the decisions of firms since the mix of inputs cannot be changed. This paper therefore investigates the impact of substitution possibilities in the production function on the optimal tax rates. Moreover, an increase in the domestic cost of production would increase prices more in a closed economy than in an open economy. Therefore the paper also investigates the impact of openness to international trade on the optimal tax rates.

With the exception of Newbury, I have not found any studies that investigate the case of optimal fiscal taxation of intermediate goods, which therefore is an obvious motive for this study. However, this study can also be related to the literature on optimal pricing of public utilities with a balanced budget requirement under economies of scale and scope, i.e. when a mark up of marginal cost is needed (Bamoul and Bradford 1970, Laffont and Tirole 1993). Such a public utility often needs to decide whether to differentiate prices between households and firms. Since socially optimal taxes on intermediate goods are determined from the social optimal prices of intermediate goods, the results concerning taxes on intermediate goods in this paper are related to this issue. Feldstein (1972) showed that the public utility should use the same pricing rule when setting prices on final consumption and prices on intermediate use. In both cases the deviation from marginal cost pricing should be a function of the price elasticity of de-

[2] At least in the Swedish Government Official Report the Diamond & Mirrlees rule has been used without an analysis of whether the tax rates on final consumption are at their optimal level, or not. Se for example SGOR 2003:38 page 139. Moreover Sørensen (2010) writes, "If the purpose is simply to raise revenue, economic theory prescribes that energy taxes should be levied only on final consumers in the household sector." In the same report he writes that an equal VAT rate probably is a preferable way to raise revenue by commodity taxation. He seems to be aware that energy taxes are non-optimal as fiscal taxes.

mand. Thus, if the price elasticities differ between households and firms, there will be a case for price differentiation between these categories.

Feldstein's analysis was made under the assumption of a Leontief technology. Later, Yang (1991) showed that his result also holds with a general technology. However, both Yang's and Feldstein's analyses are made for a closed economy, while our study considers the impact of international trade. Here, we show that the optimal commodity tax, i.e the optimal mark up on marginal cost, is dependent on the production technology. This is not a contradiction of the results of Feldstein and Yang, since the price elasticity of demand for an intermediate good is dependent on the production technology of the firm that is using that good.

Yang (1991) further states that it is not desirable to practice price discrimination among private firms as production efficiency should be preserved. Our paper shows that firms with different technologies should have different mark ups from marginal cost pricing of their inputs. This is consistent with Yang's pricing rule, taking into account the fact that price elasticities may differ between different firms. Production efficiency requires mark ups of marginal cost to be differentiated with respect to price elasticities of demand, and thus according to differences in production technology among firms using the good. In practice, this result may not be very important for tax policy, since it is difficult to estimate firm-specific price elasticities and legally difficult to give different firms different tax rates. Moreover, arbitrage makes it difficult to vary tax rates. In the empirical application of this paper we will therefore restrict the analysis to tax schemes with equal tax rates for all firms.

The purpose of this paper is to analyze numerically how the welfare maximizing proportion of the tax rates for intermediate use by firms and final consumption by households depend on different structural assumptions in the models. More specifically, we analyze the impact of elasticities in the production function and the impact of trade elasticities. We also analyse the impact of tax rates for important substitutes.

The next section of this paper derives an expression for optimal tax rates for intermediate use in a closed economy with Leontief technology. This expression provides an alternative proof of the Newberry result. In section 3 this expression is used to calculate the optimal tax rates for intermediate use in two numerical examples. In section 4 one of these examples is used to simulate optimal tax rates at various levels of the elasticity of substitution of the production function. In section 5 we also introduce international trade. Section 6 carries out simulations of electricity tax rates in an applied model of the Swedish economy under different structural assumptions. Section 7 concludes the paper.

2 Optimal taxes in the case of Leontief technology

This section considers the simplest possible case, a closed economy with Leontief technology for the use of intermediate commodities. In this case, a tax on an intermediate input would be a perfect substitute for a tax on output since the use of intermediates is always proportional to output. If tax rates for final consumption deviate from their optimal level, this could be compensated for with taxes on the use of intermediates in order to increase the price of the untaxed commodities. So it is only when tax rates for final consumption are at their optimal levels that the tax rates for intermediate use should be zero.

Proposition 1

In a closed economy with Leontief technology for intermediate use, socially optimal taxes on intermediate use should be zero, if and only if, taxes on final consumption are at their optimal levels.

Proof:
Assume perfect competition so that producer prices equal unit cost. Assume furthermore that the technology regarding intermediate inputs is Leontief while we put no restriction on the functional form for the use of factors of production. The costs of the firm consist of the use of intermediate goods times their price, plus the use of intermediate goods times the taxes paid on them plus the cost of factors of production. Thus the system of unit cost functions would be, in matrix notation;

$$\mathbf{c} = \mathbf{A}' \cdot \mathbf{c} + diag\left(\mathbf{A}' \cdot \mathbf{B}\right) + f(r, w) \qquad 2.1$$

Where
$\mathbf{c}$ = the column vector of producer prices for all commodities
$\mathbf{A}$ = the matrix of technological coefficients (commodities in rows, industries in columns).
$\mathbf{B}$ = the matrix of unit taxes or subsidies on commodities when used as intermediates in a specific industry (commodities in rows; industries in columns).
r = unit cost of capital
w = the wage rate

Solving the system of equations 2.1 for c gives:

$$\mathbf{c} = \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot \left(diag\left(\mathbf{A}' \cdot \mathbf{B}\right)\right) + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot f(r, w) \qquad 2.2$$

The vector of prices in final consumption is equal to the sum of unit costs and taxes on final consumption:

$$\mathbf{p} = \mathbf{t} + \mathbf{c} \qquad 2.3$$

where:
p = the vector of prices in final consumption
t = the vector of taxes in final consumption

Substituting 2.2 into 2.3 gives the following expression for the prices in final consumption:

$$\mathbf{p} = \mathbf{t} + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot \left(diag\left(\mathbf{A}' \cdot \mathbf{B}\right)\right) + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot f(r, w) \qquad 2.4$$

With optimal taxes on household consumption, taxes on intermediate use should be zero. The consumer prices with zero taxes on intermediate use and optimal taxes on final consumption would be:

$$\overline{\mathbf{p}} = \overline{\mathbf{t}} + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot f\left(\overline{r}, \overline{w}\right) \qquad 2.5$$

where:
$\overline{\mathbf{p}}$ = the vector of optimal prices in final consumption
$\overline{\mathbf{t}}$ = the vector of optimal taxes in final consumption
$\overline{r}$ = unit cost of capital at the optimal solution
$\overline{w}$ = the wage rate at the optimal solution
$f\left(\overline{r}, \overline{w}\right)$ = cost of factors of production (value added)

The matrix of second best tax rates (or subsidies) for intermediate use, when taxes on final consumption deviates from their optimal level, could be achieved by setting the right hand side of equation 2.4 equal to the right hand side of equation 2.5.

$$\bar{\mathbf{t}} + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot f\left(\bar{r}, \bar{w}\right) = \mathbf{t} + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot \left(diag\left(\mathbf{A}' \cdot \mathbf{B}\right)\right) + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot f\left(r, w\right) \qquad 2.6$$

If, for a non-optimal vector of tax rates for household consumption **t**, we find a matrix of tax rates for intermediate use **B** that makes equation 2.6 hold, we are able to get the optimal prices of household consumption even if the optimal tax rates for final consumption are not attainable. In this case the right hand side of 2.6 would give us the optimal consumer prices from a combination of non-optimal taxes on final consumption and compensating taxes on intermediate use.

What should the matrix of taxes on intermediate use look like? Rearranging equation 2.6:

$$\bar{\mathbf{t}} - \mathbf{t} + \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot \left(f\left(\bar{r}, \bar{w}\right) - f\left(r, w\right)\right) = \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot \left(diag\left(\mathbf{A}' \cdot \mathbf{B}\right)\right) \qquad 2.7$$

If optimal tax rates for intermediate use are zero the right hand side of equation 2.7 must be a vector of zeros. That would only be the case if $\bar{\mathbf{t}} = \mathbf{t}$. Thus proposition 1 is true. The only unlikely exception to this would be if the deviations in t affects factor prices so that, for all commodities in the economy, the change in costs of factor of production is exactly equal to the deviation from the optimal tax rate in final consumption, that is if

$$\bar{\mathbf{t}} - \mathbf{t} = \left(\mathbf{I} - \mathbf{A}'\right)^{-1} \cdot \left(f\left(\bar{r}, \bar{w}\right) - f\left(r, w\right)\right) \qquad 2.8$$

If we assume that the changes in the cost of factor of production from a change of the tax burden between intermediate use and final consumption is negligible, the system of equations 2.7 can be simplified to:

$$diag\left(\mathbf{A}' \cdot \mathbf{B}\right) = \left(\mathbf{I} - \mathbf{A}'\right) \cdot \left(\bar{\mathbf{t}} - \mathbf{t}\right) \qquad 2.9$$

To see the intuition behind equation 2.9, consider the case where only electricity is taxed. If so, it has to be taxed even when used as an intermediate good. The tax on electricity will in that case increase the prices of the other commodities as well, and leave the relative prices of final consumption undisturbed.

3 Commodity taxation with Leontief technology

In this section, two numerical examples are used to exemplify the conclusion from the previous section. The second example will later be extended to study open economy models with substitution possibilities in the production functions. In all examples only one of the commodities is taxed and we will investigate different proportions of the tax rate for intermediate and final demand use of this commodity.

Example 1

Assume a closed economy with three commodities (1, 2 and 3) produced separately in three industries (1, 2 and 3). Consumption is determined from maximization of a Cobb-Douglas utility function with equal cost shares for all commodities. In the production functions there is Leontief technology for the use of intermediate goods. Using the notation of section 2, the matrix of technological coefficients (the use of a specific commodity per unit of output) with commodities in rows and industries in columns, is;

$$\mathbf{A} = \begin{bmatrix} 0 & 0.5 & 0.2 \\ 0 & 0 & 0.2 \\ 0 & 0 & 0 \end{bmatrix} \tag{3.1}$$

Assume though that for some reason only commodity 1 is taxed, i.e., all elements of the second and third rows in the t vector and B matrix are equal to zero.

$$\mathbf{B} = \begin{bmatrix} b_{1,1} & b_{1,2} & b_{1,3} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{3.2}$$

$$\mathbf{t} = \begin{bmatrix} t_1 \\ 0 \\ 0 \end{bmatrix} \tag{3.3}$$

Due to the Cobb-Douglas utility function, price elasticities are equal for all three commodities. Therefore, the optimal household tax rates will also be equal for all three commodities. Denote government consumption, financed by taxes on commodities, with G. The optimal household tax rate for all commodities is then G/C, where C is total household consumption.

Since

$$\bar{\mathbf{t}} = \begin{bmatrix} G/C \\ G/C \\ G/C \end{bmatrix} \tag{3.4}$$

$$\mathbf{A}' \cdot \mathbf{B} = \begin{bmatrix} 0 & 0 & 0 \\ 0.5 \cdot b_{1,1} & 0.5 \cdot b_{1,2} & 0.5 \cdot b_{1,3} \\ 0.2 \cdot b_{1,1} & 0.2 \cdot b_{1,2} & 0.2 \cdot b_{1,3} \end{bmatrix} \tag{3.5}$$

and

$$\mathbf{I} - \mathbf{A}' = \begin{bmatrix} 1 & 0 & 0 \\ -0.5 & 1 & 0 \\ -0.2 & -0.2 & 1 \end{bmatrix} \tag{3.6}$$

the system of equations 2.9 is:

$$\begin{bmatrix} 0 = \dfrac{G}{C} - t_1 \\ 0.5 \cdot b_{1,2} = -0.5 \cdot \left(\dfrac{G}{C} - t_1 \right) + \dfrac{G}{C} \\ 0.2 \cdot b_{1,3} = -0.2 \cdot \left(\dfrac{G}{C} - t_1 \right) - 0.2 \dfrac{G}{C} + \dfrac{G}{C} \end{bmatrix} \tag{3.7}$$

This can be simplified to:

$$\begin{cases} t_1 = \dfrac{G}{C} \\ b_{1,2} = 2\dfrac{G}{C} \\ b_{1,3} = 4\dfrac{G}{C} \end{cases} \qquad 3.8$$

To reach the optimal solution the tax on commodity 1 must result in a proportional price increase for all three commodities leaving relative prices undisturbed. From 3.8 it can be seen that the optimal tax rate in industry 2 should be twice as high and in industry 3 four times as high as the household tax rate. Since industry 2 uses 0.5 units of commodity 1 per produced unit of commodity 2, the price increase of commodity 2 in final consumption would be 0.5 times the tax rate and thus equal to the price increase of commodity 1. Since industry 3 uses 0.2 units of commodity 1 per unit of commodity 3, the price increase of commodity 3 from tax payments in industry 3 is 80 percent of the price increase of commodity 1. However the price of commodity 3 is also increased from the use of good 2 and therefore the price increase will be equal for all three commodities.

In this case the optimal solution could be achieved, although only one of the commodities is taxed, by using higher taxes on intermediate use than on final consumption. In the optimal solution the tax rates differ for industry 2 and industry 3 since the optimal deviation from marginal cost pricing depends on the technologies of the two industries. This result is thus a contradiction of the statement by Yang (1991) that price discrimination between firms will reduce efficiency in production. Production efficiency requires the mark up over marginal cost to be differentiated according to price elasticities of demand, and thus according to the production technology of the different firms using the good.

Example 2

Let us now consider the case where one of the industries neither produces nor uses the taxed commodity. Assume an economy equal to the previous example 1 in all aspects but for the input-output matrix. Assume the following matrix of technological coefficients:

$$\mathbf{A} = \begin{bmatrix} 0 & 0.5 & 0 \\ 0 & 0 & 0.2 \\ 0 & 0 & 0 \end{bmatrix} \qquad 3.9$$

The system of equations 2.9 would in this case be:

$$\begin{cases} 0 = \frac{G}{C} - t_1 \\ 0.5 \cdot b_{1,2} = -0.5 \cdot \left(\frac{G}{C} - t_1 \right) + \frac{G}{C} \\ 0 = -0.2 \cdot \left(\frac{G}{C} - t_1 \right) - 0.2 \cdot \frac{G}{C} + \frac{G}{C} \end{cases} \qquad 3.10$$

where the first and third equation cannot hold for the same level of t_1. In this case, the optimal solution is not attainable by just taxing commodity 1. Since there is just one tax rate, $b_{1,2}$, to manipulate, it is not possible to get optimal prices for both commodity 2 and commodity 3. The tax on commodity 1 has no impact in industry 3 since industry 3 neither uses nor produces commodity 1.

The first best solution is not attainable, but what are the second best tax rates for households and intermediate use in industry 2? In the following the economy in example 2 is analysed in a Computable General Equilibrium (CGE) model.[3] We evaluate social welfare under different proportions of tax rates for intermediate use by firms and final consumption by households. In section 4 the same tax proportions are used for a case where there are substitution possibilities in the production function, and in section 5 for the open economy case. Comparing the results from these different cases

[3] For all simulations the standard CGE model SAINT1.01 is used. For a full documentation of the model see Bohlin 2010. For more details of the simulations in this paper and download of the GAMS code see

http://www.natskolan.se/research/saint/comtax.htm illustrates how the welfare optimizing proportion of tax rates for intermediate and final use differs in different structures of the economy if we only tax one commodity. For these simulations, a social accounting matrix, SAM, is needed.

Let the economy in example 2, when the optimal household taxes G/C are used, be described by the SAM in Table 3.1. The SAM describes payments going from the columns to the rows. A1 to A3 denote the three private industries producing the three private goods C1-C3, and A4 denotes production of C4 that is used in government consumption. L and K denote labour and capital. Investments are found in the "Saving Investment" column while savings are found in the "Saving Investment" row. Household consumption is measured in basic prices, i.e. commodity taxes are excluded. In the row "Taxes" the ad valorem commodity taxes on the three commodities are collected and redistributed to the government in the "Taxes" column. Since the optimal household tax rates are equal to G/C, the ad valorem tax rates in final consumption in the above SAM are equal to 11 percent ofor all commodities. While intermediate goods are used under Leontief technology, the elasticity of substitution between capital and labour is assumed to be 0.8. The utility function of the representative household is a Cobb Douglas with equal cost shares for all three commodities.

Table 3.1 The social accounting matrix of the closed economy in the optimal solution

	Expenditures														
	Industries				Commodities				Taxes	Factors		House-holds	Govern-ment	Savings investment	SUM
Receipts	A1	A2	A3	A4	C1	C2	C3	C4		L	K				
A1					25										25
A2						20									20
A3							25								25
A4								5							5
C1		10										15			25
C2			5									15			20
C3												15		10	25
C4													5		5
Taxes												5			5
Labour	17	6	13	4											40
Capital	8	4	7	1											20
Households										40	20				60
Government									5						5
S-I												10			10
SUM	25	20	25	5	25	20	25	5	5	40	20	60	5	10	

Now, assume instead that government consumption is financed by a tax on commodity 1 leaving the other commodities untaxed. What is then the optimal proportion between the tax rates on household consumption of commodity

1 and the use of commodity 1 as intermediate input in industry 2? In Table 3.2 the change in welfare, compared to the case where all taxes are levied on household consumption, is reported for some different proportions of these tax rates. Welfare is evaluated from the change in the consumption bundle when the tax rate for intermediate use in firms is successively increased from zero. The welfare measure used is the equivalent variation in percent of household consumption. The tax rates are chosen in order to give a balanced government budget. To facilitate comparisons of the different structural assumptions of the economy, the same proportions between the tax rates for households and firms will be used in later simulations.

Table 3.2 Welfare gain from taxes on intermediate goods, at different levels of tax rates and Leontief technology

Ad valorem tax rates			Welfare
$b_{1,2}/t_1$	t_1 Households	$b_{1,2}$ Firms	Equivalent Variation (percentage of private consumption)
0	42.8%		0.00
1/9	37.5%	4.2%	0.34
1/4	32.9%	8.2%	0.61
3/7	28.7%	12.3%	0.82
2/3	24.8%	16.5%	0.99
1	21.0%	21.0%	1.11
3/2	17.2%	25.8%	1.20
7/3	13.4%	31.2%	1.23
4	9.4%	37.5%	1.20
9	5.0%	45.2%	1.08
∞		55.5%	0.81

The highest welfare is thus achieved with a tax rate of 13.4 percent for final demand by households and 31.2 percent for intermediate use by firms. These are the second best tax rates if it is only possible to tax commodity 1. The increase in welfare using these tax rates is 1.23 percent of household consumption, compared to the case where the tax rate for intermediate use is zero.

4 Commodity taxation with substitution possibilities

This section investigates the impact of substitution possibilities in the production function on the welfare maximizing proportion of the tax rates for intermediate use by firms and final consumption by households.

Example 3

Assume the same economy as in example 2, except that the production function is a nested CES function where the elasticity of substitution between the intermediate good and labour is either 0.8 or 2.0. In both cases, the elasticity of substitution between the intermediate-labour composite and capital is 0.8. The welfare effects of the different proportions of the tax rates between households and firms are reported in Table 4.1.

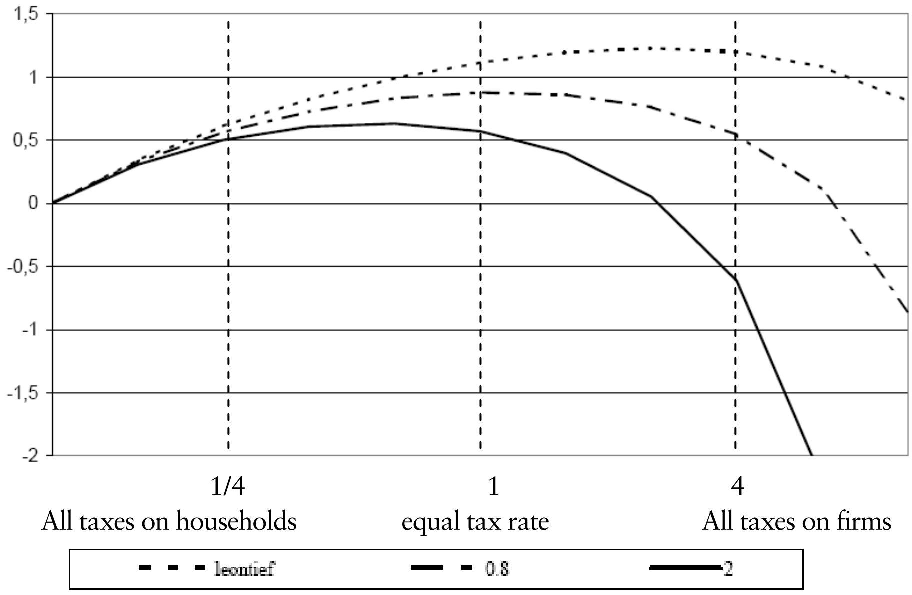
Table 4.1 Welfare gain from taxes on intermediate goods, at different levels of tax rates and elasticities of substitution

	Elasticity of substitution = 0.8			Elasticity of substitution = 2.0		
	Ad valorem tax rates		EV*	Ad valorem tax rates		EV*
$b_{1,2}/t_1$	t_1 Households	$b_{1,2}$ Firms		t_1 Households	$b_{1,2}$ Firms	
0	42.8%	0.0%	0.00	42.8%	0.0%	0.00
1/9	37.6%	4.2%	0.33	37.8%	4.2%	0.31
1/4	33.2%	8.3%	0.56	33.6%	8.4%	0.50
3/7	29.2%	12.5%	0.73	29.9%	12.8%	0.61
2/3	25.5%	17.0%	0.83	26.5%	17.6%	0.63
1	21.9%	21.9%	0.88	23.2%	23.2%	0.57
3/2	18.3%	27.4%	0.86	20.0%	30.0%	0.40
7/3	14.6%	34.0%	0.76	16.7%	38.9%	0.05
4	10.6%	42.5%	0.54	13.1%	52.3%	-0.61
9	6.0%	54.3%	0.11	8.8%	79.6%	-2.19
∞	0.0%	74.7%	-0.85	0.0%	**	**

**EV measured as percentage of household consumption. **If only intermediate use is taxed there is no tax rate that gives a balanced budget. Tax revenue is maximized at a tax rate of 1.6 but is not enough to cover government expenditure, the government deficit is then 0.9, i.e., 18% of public expenditure.*

Figure 4.1 summarizes the results from examples 2 and 3. The X-axis shows the distribution of the tax burden on firms and households. The Y-axis shows the welfare, measured as equivalent variation in percentage of household consumption, compared to the case when all taxes are collected from final consumption. Although the 11 quotas of the tax rates are the same in all three cases, the levels of the tax rates differ. With substitution possibilities in the production function, the tax will be more distortionary and higher tax rates are needed to give a balanced government budget.

Figure 4.1 Welfare gain from taxes on intermediate goods, at different levels of tax rates and elasticities of substitution.
(Equivalent variation as percentage of household's consumption)



From Figure 4.1 it can be seen that when the elasticity of substitution between intermediate input and labour is increased, the optimal proportion between the tax rates for intermediate use and final consumption moves towards higher taxes on final consumption. The interpretation is that if there are substitution possibilities in the production function the intermediate tax will be disturbing for the production process. This implies a larger welfare cost and outweighs the gain from equalizing consumer prices. However the optimal tax rate on intermediate use is still far from zero.

5 Commodity taxation in an open economy

This section investigates the impact of international trade on the welfare maximizing proportion of the tax rates for intermediate use by firms and final consumption by households.

Example 4

In our final example the economy is assumed to be equal to the economy in example 3 in all aspects but for access to international trade. There is export of private goods amounting to 20 percent of the production. The trade is balanced in all three commodities, i.e., the economy has no comparative advantages. This assumption minimizes the differences to the previous examples. The social accounting matrix of the optimal solution is shown in Table 5.1, where RoW denotes the rest of the world.

Table 5.1 The social accounting matrix of the open economy

	Expenditures															
	Industries				Commodities				T	Factors		H	G	S-I	RoW	SUM
Receipts	A1	A2	A3	A4	C1	C2	C3	C4		L	K					
Industry A1					25											25
Industry A2						20										20
Industry A3							25									25
Industry A4								5								5
Commodity C1		10										15			10	35
Commodity C2			5									15			8	28
Commodity C3												15		10	10	35
Commodity C4													5			5
Taxes												5				5
Labour	17	6	13	4												40
Capital	8	4	7	1												20
Households										40	20					60
Government									5							5
Savings & Investments												10				10
Rest of the World					10	8	10									28
SUM	25	20	25	5	35	28	35	5	5	40	20	60	5	10	28	

Import is modelled by use of the Armington assumption with an elasticity of substitution between import and domestic production of 0.8 (low) or 1.5 (high). Export is modelled using a constant elasticity of transformation of 1.5 (low) or 3 (high) between export and domestic sales. The elasticity of substitution between the intermediate good and labour in the production function are in all three cases equal to 0.8. The results of the model simulations with these assumptions are shown in Table 5.2.

Table 5.2 Welfare gain from taxes on intermediate goods, at different levels of tax rates and trade elasticities

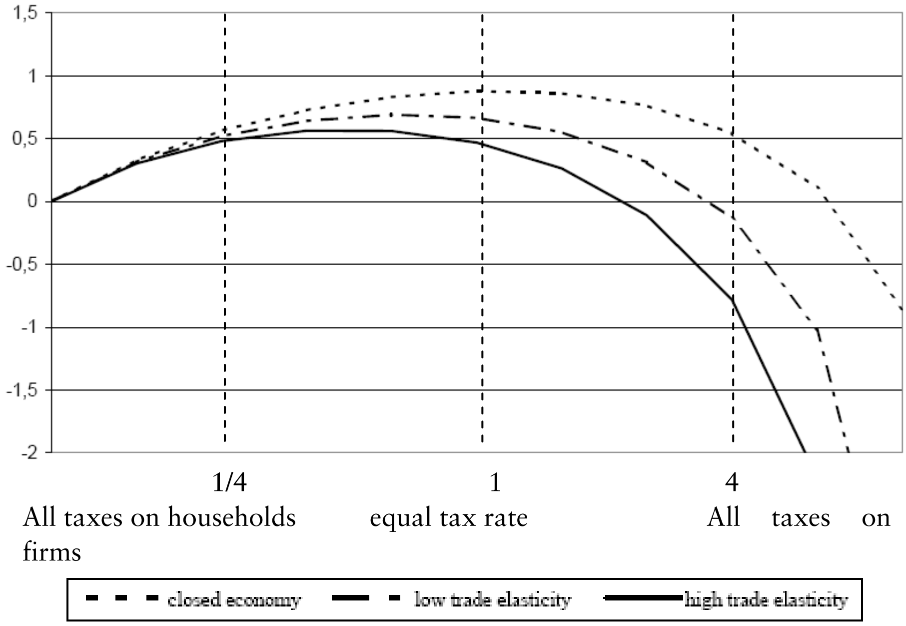
	Low trade elasticities			High trade elasticities		
	Ad valorem tax rates		EV*	Ad valorem tax rates		EV*
$b_{1,2}/t_1$	t_1 Households	$b_{1,2}$ Firms		t_1 Households	$b_{1,2}$ Firms	
0	42.8%		0.00	42.8%		0.00
1/9	37.7%	4.2%	0.32	37.8%	4.2%	0.30
1/4	33.4%	8.4%	0.52	33.7%	8.4%	0.48
3/7	29.6%	12.7%	0.64	30.1%	12.9%	0.56
2/3	26.1%	17.4%	0.69	26.8%	17.9%	0.56
1	22.8%	22.8%	0.66	23.7%	23.7%	0.47
3/2	19.4%	29.2%	0.55	20.6%	30.9%	0.26
7/3	16.0%	37.2%	0.31	17.4%	40.5%	-0.11
4	12.1%	48.5%	-0.13	13.8%	55.2%	-0.78
9	7.5%	67.2%	-1.02	9.3%	84.1%	-2.19
∞	42.8%	119.5%	-3.68		319.9%	-10.41

**EV measured as percentage of household consumption*

Figure 5.1 compares these results with the closed economy results. The X-axis shows the distribution of the tax burden on firms and households. Although the quotas of the tax rates are the same in all three cases, the levels of the taxes differ. In the open economy case the distortions from the tax will be higher, and therefore higher tax levels are needed to give a balanced government budget.

From Figure 5.1 it can be seen that when openness is increased the optimal proportion between the tax rates for intermediate use and final consumption moves towards higher taxes on final consumption. The reason is that, in the open economy, prices will be more dependent on foreign prices. An increase in the tax rates for intermediate goods will thus have lower impact on prices in final consumption. It would be less effective to use taxes on intermediate goods to compensate deviation from optimal tax rates in final consumption.

Figure 5.1 Welfare gain from taxes on intermediate goods, at different levels of tax rates and trade elasticities (Equivalent variation as percentage of household's consumption)



6 Electricity taxes in Sweden

This section evaluates the empirical relevance of the findings from the stylised models using the electricity tax in Sweden as an example. For this purpose we assume that the tax on electricity is a fiscal tax and we estimate welfare implications from different proportions of the tax rates for intermediate use by firms and final consumption by households just as in the previous sections. Moreover, we investigate how the optimal proportion of the electricity tax rates for intermediate use by firms and final consumption by households depends upon the corresponding proportion of tax rates for substitutes for electricity.

The same proportions of tax rates as were evaluated in the stylised model are evaluated in four different versions of an applied computable general equilibrium (CGE) model of the Swedish economy. The four versions of the model differ with respect to the elasticity of substitution in production functions and price elasticities in import demand and export supply functions. The model is static and calibrated with data from 2001. For a complete description of the model, see Bohlin 2010. The four versions are illustrated in Table 6.1.

Table 6.1 The four model versions

		Trade elasticities	
		Low	High
Elasticity of substitution in the production function.	0	1	
	Low	2	
	High	3	4

In the first model version all intermediate inputs are used under Leontief technology and the trade elasticities are low. In the second model version substitution possibilities are introduced for energy and transport services, but with low elasticities of substitutions. The third model version has a high elasticity of substitution, but still low trade elasticities while, finally, in the fourth model version both trade and substitution elasticities are high. Model versions 2, 3 and 4 can be seen as bounds on the realistic values of the elasticities. The assumption of a Leontief technology, however, is unrealistic as a description of the long-run possibilities of substituting between different kinds of energy.

The welfare effects of the different proportions of tax rates are evaluated from changes in private consumption compared to actual Swedish tax rates for electricity in 2001, 0.18 SEK per kWh for households and services and 0 for agriculture, mining and manufacturing. The welfare measure used is, as before, the equivalent variation in percent of household consumption. Since we assume that the electricity tax is a fiscal tax, all emissions and other externalities are excluded in the calculation of equivalent variation. The tax rates are chosen in order to meet a requirement of a balanced government budget. We only report the results for those proportions of tax rates where it is possible to meet the balanced budget constraint. The results are shown in Table 6.2 and Figure 6.1.

Table 6.2 Increase in welfare from changes in tax rate for electricity; equivalent variation as percentage of household consumption

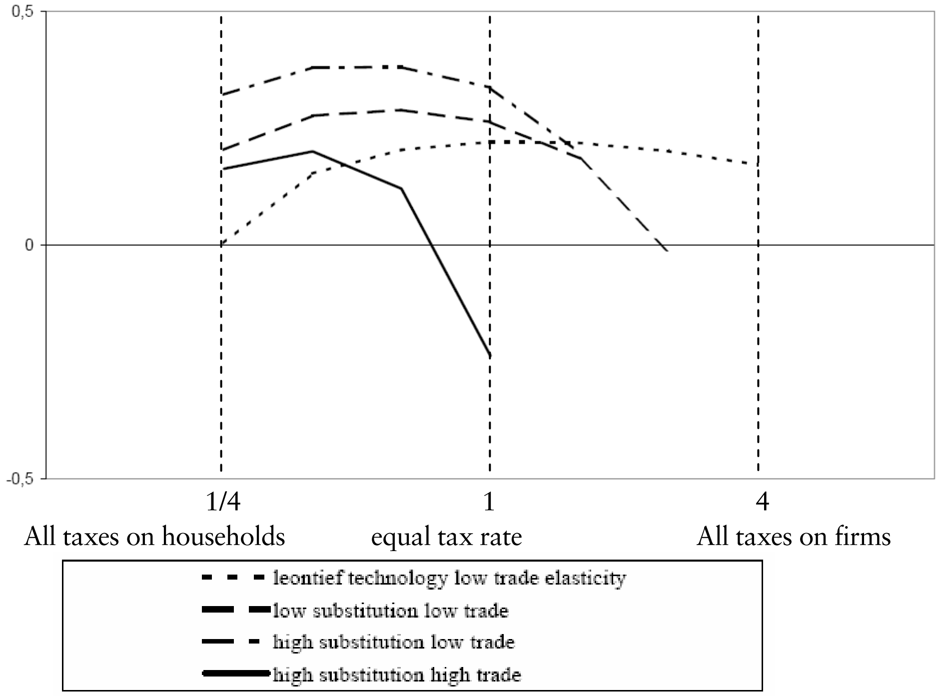
$\frac{t_f}{t_h}$	Leontief technology Low trade elasticity	Low elasticity of substitution Low trade elasticity	High elasticity of substitution Low trade elasticity	High elasticity of substitution High trade elasticity
0				
1/9				
1/4	0.004	0.203	0.321	0.163
3/7	0.152	0.276	0.379	0.200
2/3	0.203	0.288	0.380	0.120
1	0.220	0.262	0.336	-0.238
3/2	0.218	0.185	0.197	
7/3	0.200	-0.013		
4	0.171			
9				
∞				

tf = electricity tax rate for firms, th = electricity tax rate for households

The welfare effects of changing taxes on electricity are small; the highest increase in welfare is lower than 0.5 percent of household consumption. But we find the same qualitative results as in the stylised model. The welfare maximizing proportion, between the tax rates for intermediate use by firms and final demand by households, declines with higher elasticities of substitution in production functions and higher price elasticities in import demand functions and export supply functions.

In all the three more realistic model versions the welfare maximizing tax rates are higher for households than for firms. The explanation for this is that manufacturing has lower tax rates for fossil fuels. If actors with high tax rate for fossil fuels also have a high tax rate for electricity, the distortion of relative prices between these substitutes is minimized.

Figure 6.1 Increase in welfare from changes in tax rate for electricity; equivalent variation as percentage of household consumption.



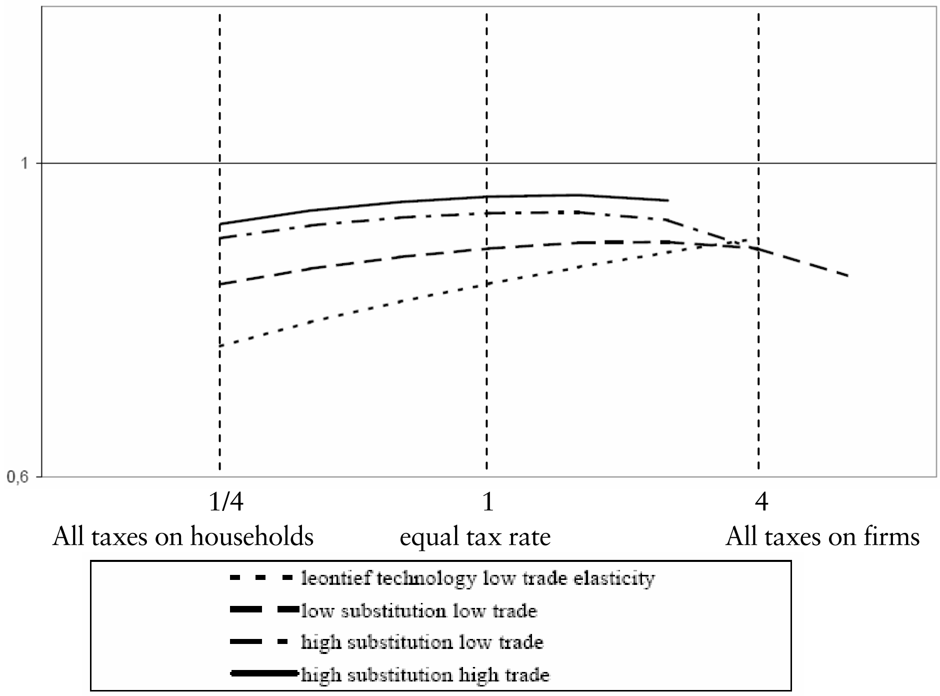
In Table 6.3 the same proportion of tax rates for electricity is instead evaluated in a case with equal tax rates for fossil fuel for all users. The results of these simulations show that in this case the electricity tax rate for households should not be higher than the tax rates for firms. The findings on the impact of the different elasticities on the optimal proportions of tax rates between households and firms are qualitatively the same in this case as in the previous.

Table 6.3 Increase in welfare from changes in tax rates for electricity and fossil fuels; equivalent variation as percentage of household consumption

$\frac{t_f}{t_h}$	Leontief technology Low trade elasticity	Low elasticity of substitution Low trade elasticity	High elasticity of substitution Low trade elasticity	High elasticity of substitution High trade elasticity
0				
1/9				
1/4	0.766	0.845	0.904	0.922
3/7	0.797	0.865	0.920	0.939
2/3	0.823	0.880	0.930	0.950
1	0.846	0.891	0.936	0.957
3/2	0.867	0.898	0.937	0.959
7/3	0.886	0.899	0.927	0.952
4	0.904	0.891	0.889	
9		0.856		
∞				

tf = electricity tax rate for firms, th = electricity tax rate for households

Figure 6.2 Increase in welfare from changes in tax rates for electricity and fossil fuels; equivalent variation as percentage of household consumption



In table 6.3 we see that equal tax rates for energy for households and firms increase welfare. Taxes on firms reduce efficiency in production by distorting the input mix in firms. But taxes on firms also increase efficiency since they increase the price of non-energy commodities produced with energy as input. Thereby, we come closer to the situation with an equal tax rate for all commodities, and reduce the distortion introduced by taxing energy more heavily than other commodities. In the Leontief case, when the input mix in production cannot be disturbed, only the second effect is present and thus tax rates should be much higher for intermediate use by firms than for final consumption by households.

7 Conclusions and discussion

This paper investigates the case for taxes on intermediate inputs to compensate for deviation from optimal taxation of final consumption. Newbury showed, in a closed economy with Leontief technology, that taxes on intermediate use should be larger than zero when taxes on final consumption deviate from their optimal level. In this paper the Newbury result is extended to open economies with substitution possibilities in the production function. Moreover, we show that the welfare maximizing proportions of tax rate in different cases depend on different structural assumptions of the economy.

It is shown that the optimal solution is possible to achieve under Leontief technology, even if only one of the commodities is taxed, if the taxed input is used in all industries producing the untaxed output. In that case the tax structure that maximizes welfare has higher tax rates for firms than for households. The welfare maximizing tax rate may also differ between different firms if they use different technologies.

If there are possibilities of substitution for different inputs in the production process, taxes on intermediate use will be more disturbing and the tax rates that maximize welfare will be reduced for firms and increased for households. Introducing international trade makes domestic prices more dependent on the world market prices. Thus, the prices in final consumption cannot be influenced to the same degree by taxes on intermediate inputs and the welfare maximizing tax rates for firms are even lower. These results are shown both in stylized models and in an applied model of the Swedish economy with the tax on electricity as an example. The applied model also shows that the welfare maximizing proportions of the tax rates for intermediate use and final consumption for one commodity will depend upon the proportions of the tax rates for important substitutes for that commodity.

In the empirical application we find that energy taxes with fiscal purposes should be equal for final consumption by households and intermediate use by firms. The Diamond and Mirrlees principle calls for higher taxes on households than on firms to avoid disturbance of the input choices in production. The Newbury principle calls for higher taxes on firms than on households to achieve the same proportional price increases for energy and non-energy commodities. In our model these principles seem to cancel each other and call for equal tax rates for households and firms.

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Appendix 1 Elasticities in the empirical model

Trade elasticities

The trade elasticities used in the empirical model of the Swedish economy are shown in Table A1. The first two columns give the elasticities in simulations with low trade elasticities, while the other two columns show the elasticities in simulations with high trade elasticities.

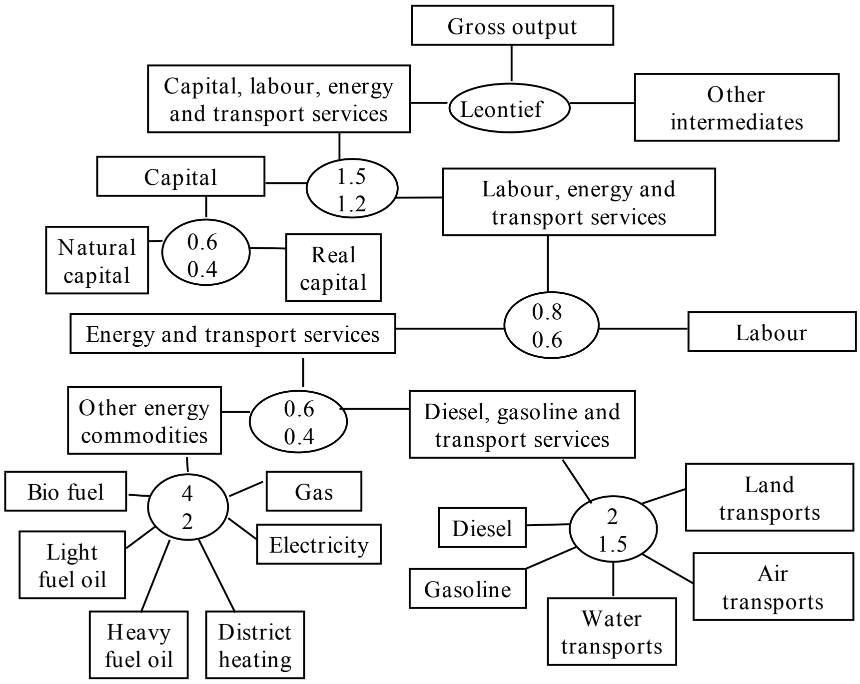
Table A1 Trade elasticities
(Price elasticities in import demand and export supply functions)

Commodity	Low trade elasticities		High trade elasticities	
	import	export	import	export
Products from Agriculture, forestry, fishing	1.32	3.12	2.475	5.85
Mining and quarrying products	1.32	3.12	2.475	5.85
Food, textile and wearing apparel	1.32	3.12	2.475	5.85
Wood and of products of wood, publishing	1.32	3.12	2.475	5.85
Pulp, paper and paper products	1.32	3.12	2.475	5.85
Gasoline	1.8	3.6	3.375	6.75
Diesel	1.8	3.6	3.375	6.75
Jet fuels	1.8	3.6	3.375	6.75
Light fuel oil	1.8	3.6	3.375	6.75
Heavy fuel oil	1.8	3.6	3.375	6.75
Other refined petroleum products	1.8	3.6	3.375	6.75
Other energy intense manufacturing products	1.32	3.12	2.475	5.85
Other manufacturing products	1.32	3.12	2.475	5.85
Electricity	2.4	3.6	4.5	6.75
Distribution of water. Construction services	0.6	0.96	1.125	1.8
Retail trade services	0.6	0.96	1.125	1.8
Hotel services, financial services, post	0.96	1.44	1.8	2.7
Land transports	0.96	1.44	1.8	2.7
Water Transports	1.8	3.6	3.375	6.75
Air transports	1.8	3.6	3.375	6.75
Real estate services, Renting of equipment, R&D	0.6	0.96	1.125	1.8
Other business services	0.6	0.96	1.125	1.8
Public services	0.6	0.96	1.125	1.8
Other services	0.72	1.44	1.35	2.7

Elasticities and nest structure of production function

The elasticities of substitution in the production function are shown in figure A1. The top number in each ellipse refers to simulations with high elasticities of substitutions, and the bottom number to simulations with low elasticities of substitution.

Figure A1 Production functions in the empirical model

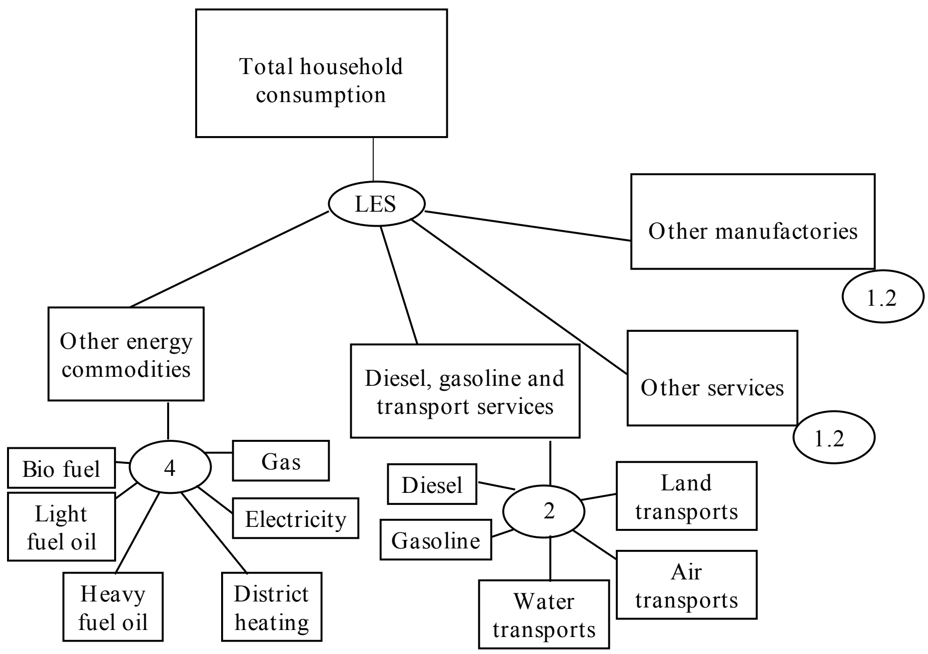


The numbers in ellipses refers to the elasticity of substitution between the aggregates. The top number is the high elasticity and the bottom number is the low elasticity.

Elasticities and nest structure of household demand

There is one representative household in the model. Consumer behaviour is described in Figure 2.2. It is modelled as a LES-CES nested system with a LES system at the top aggregating four commodity groups: diesel gasoline and transport services, other energy commodities, other manufactories and other services. Within these four aggregates there are CES equations.

Figure A2 Household demand functions in the empirical model



The numbers in ellipses refers to the elasticity of substitution between the commodities.